APPENDIX A

Temperature and Fishery Analysis of Mechanized Temperature Control Device at Folsom Dam

Temperature and Fishery Analysis of Mechanized Temperature Control Device at Folsom Dam

Prepared for

Sacramento Area Flood Control Agency

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Purpose and Scope

In its Long-Term Agreement with the U.S. Bureau of Reclamation (Reclamation), the Sacramento Area Flood Control Agency (SAFCA) is committed to cooperate with Reclamation in designing and implementing improvements to Folsom Dam and/or its auxiliary facilities that will improve Reclamation's ability to manage the temperature of water stored in the reservoir and released to the Lower American River (LAR). As mitigation for the SAFCA proposed Folsom Dam re-operation, modifications to the current temperature control device (temperature control device) have been proposed. This analysis was undertaken to examine the potential to improve temperature management capability beyond the level of the proposed modifications by implementing a fully mechanized temperature control device at the Folsom Dam penstock intakes. The device would allow more flexibility in ability to withdraw from differing levels in the reservoir and to change the withdrawal level settings to meet release temperature goals. This report summarizes the analysis performed and the temperature and fishery impacts of this potential enhancement.

Introduction

Folsom Reservoir Management Objectives

Folsom Reservoir is managed to fulfill the multipurpose objectives of the Central Valley Project (CVP), namely: flood control, water supply, fish and wildlife protection, recreation, and power production. Because of the finite nature of the hydrologic water supply, each of these multipurpose objectives is affected by the others in terms of determining operational management choices (magnitude and frequency of river releases, time of year, reservoir elevation and storage, cold-water management strategy) and management priorities.

Reservoir cold-water management and fishery flow management principles emphasize the capture of winter and spring cold reservoir inflows to create a cold-water reserve to be released during the summer and fall months for LAR fishery objectives. Reservoir fishery flow management principles also must consider the lifestage and habitat needs of the resident fishery. To maximize the cold-water reserve in a single reservoir, flood control objectives would be minimized in favor of the greatest retention of available winter and spring cold-water inflows. To maximize fishery flow management in a single reservoir, flood control objectives would be minimized in favor of allowing the greatest flexibility to manage for flow. Providing a desired level of flood control protection against extreme hydrologic events requires an operational tradeoff between capturing inflow for water supply objectives and the operational ability to safely release potentially large inflow volumes.

Lower American River Fisheries Protection Temperature Objectives

The LAR currently supports more than 40 fish species, including native and introduced resident and anadromous species. Steelhead and fall-run chinook salmon are among the fish species currently occurring in the river. The listing of steelhead as threatened and the candidate listing of fall-run chinook salmon under the federal Endangered Species Act have resulted in their becoming the river's fish species of highest management concern.

The critical period for temperature control to benefit steelhead is July through September when juvenile steelhead are rearing in the river. The critical period for fall-run chinook salmon is October and November when peak spawning occurs. Fall-run chinook salmon juveniles emigrate from the river by the end of June and, therefore, are not present during the July through September period. Managing Folsom Reservoir release temperatures for the sole benefit of steelhead in the summer would adversely affect fall-run chinook salmon spawning in the fall. Conversely, conserving cold-water throughout the summer and releasing it in the fall would benefit fall-run chinook salmon, but would result in higher summer temperatures for steelhead. Hence, from a biological and logistical basis, balanced management of Folsom Reservoir's cold-water pool is necessary on an annual basis in order to maximize temperature benefits to both steelhead and fall-run chinook salmon.

River water temperatures are affected by river flow rates, meteorology, and the temperature of water released from Folsom Reservoir. The temperature of water released from Folsom Reservoir has a significant effect on LAR temperatures. Within the constraints of annual water availability (i.e., hydrology conditions of the year), LAR flows are dictated by releases from Folsom Reservoir that balance in-river, local water supply, and Delta needs as a part of integrated CVP/State Water Project (SWP) operations. As such, instream flows and temperatures receive substantial attention from numerous parties on a monthly basis through the forum of the Lower American River Operations Workgroup.

Construction of Folsom and Nimbus dams prevented American River fall-run chinook salmon from reaching the majority of their historic spawning habitat. Hence, their current populations are supported by spawning and initial rearing within the 23 miles of the LAR and by artificial production at the Nimbus Hatchery. Seasonal LAR temperatures and flows, the primary limiting factors to the river's steelhead and fall-run chinook salmon populations, are controlled by operations of Folsom Dam and Reservoir. Therefore, the operations of Folsom Dam and Reservoir will largely influence maintenance and restoration of LAR steelhead and fall-run chinook salmon populations.
Within the constraints of annual water availability (i.e., hydrologic conditions of the year), LAR flows are dictated by releases from Folsom Reservoir that balance in-river, local water supply, and Delta needs as a part of integrated CVP/SWP operations. As such, instream flows receive substantial attention by numerous parties on a monthly basis, which results in effective flow management.

River water temperatures are affected by river flow rates, meteorology, and the temperature of water released from Folsom Reservoir. The latter factor, the temperature of water released from Folsom Reservoir, has a significant effect on LAR temperatures, yet relatively little attention has been given in the past to managing the temperature of water released from Folsom Reservoir throughout each year. Consequently, LAR water temperatures could be improved annually to benefit steelhead and fall-run chinook salmon by improving the management of Folsom Reservoir release temperature.

Folsom Reservoir Cold-Water Pool Management

Seasonal water temperature at Folsom Reservoir and the LAR are lowest during the winter, increase through the spring, are highest during the summer and decrease again in the fall. Inflow stored during the filling of Folsom Reservoir will gradually increase in temperature through the spring and into summer. Since cooler water is denser than warmer water, Folsom Reservoir will develop a stratification of temperature, with cooler water at the bottom.

Optimal Cold-Water Pool Management is defined as the biologically most efficient use of the reservoir's seasonally available cold-water. Strategic releases of water from the cold-water pool, in lieu of releases at higher reservoir levels, can provide seasonal benefits for LAR fisheries resources. The temperature of water released from Folsom Reservoir is manipulated by releasing water from various elevations through the temperature control shutters on each penstock intake. There are two tradeoffs that must be recognized to accomplish Optimal Cold-Water Pool Management, release temperature vs. release rate and seasonal, Summer vs. Fall cold-water use.

Cold-water conserved in Folsom Reservoir and released into the LAR during the summer will, over time, increase in temperature in the river. The higher the flow in the river, the less the increase in temperature will be between the dam and a given point downstream. This occurs for two reasons, at higher flows water typically travels faster, therefore it takes less time for the water to reach a certain point and at higher flows, the surface area to volume ratio is usually less (the majority of heat exchange occurs at the surface).

For a given river location/water temperature, there is an optimal release rate/release temperature combination that maximizes remaining cold-water availability in Folsom Reservoir. In modeling Folsom Reservoir integrated CVP/SWP operations, temperature objectives are only indirectly satisfied by releases made for flood control, water supply, environmental, and hydropower objectives. In some periods, release rates may be so low that desired water temperatures are unachievable. Seasonal cold-water availability is limited by initial reservoir storage and the rate of ambient warming in Folsom Reservoir. Annual balanced management of Folsom Reservoir's cold-water pool is necessary in order to maximize temperature benefits to both steelhead and fall-run chinook salmon. Cold-water released in the summer cannot be released again in the fall. If meteorological conditions are severe enough, even cold-water conserved in the early part of summer may be lost to ambient warming of Folsom Reservoir.

Existing Temperature Control Shutter Management

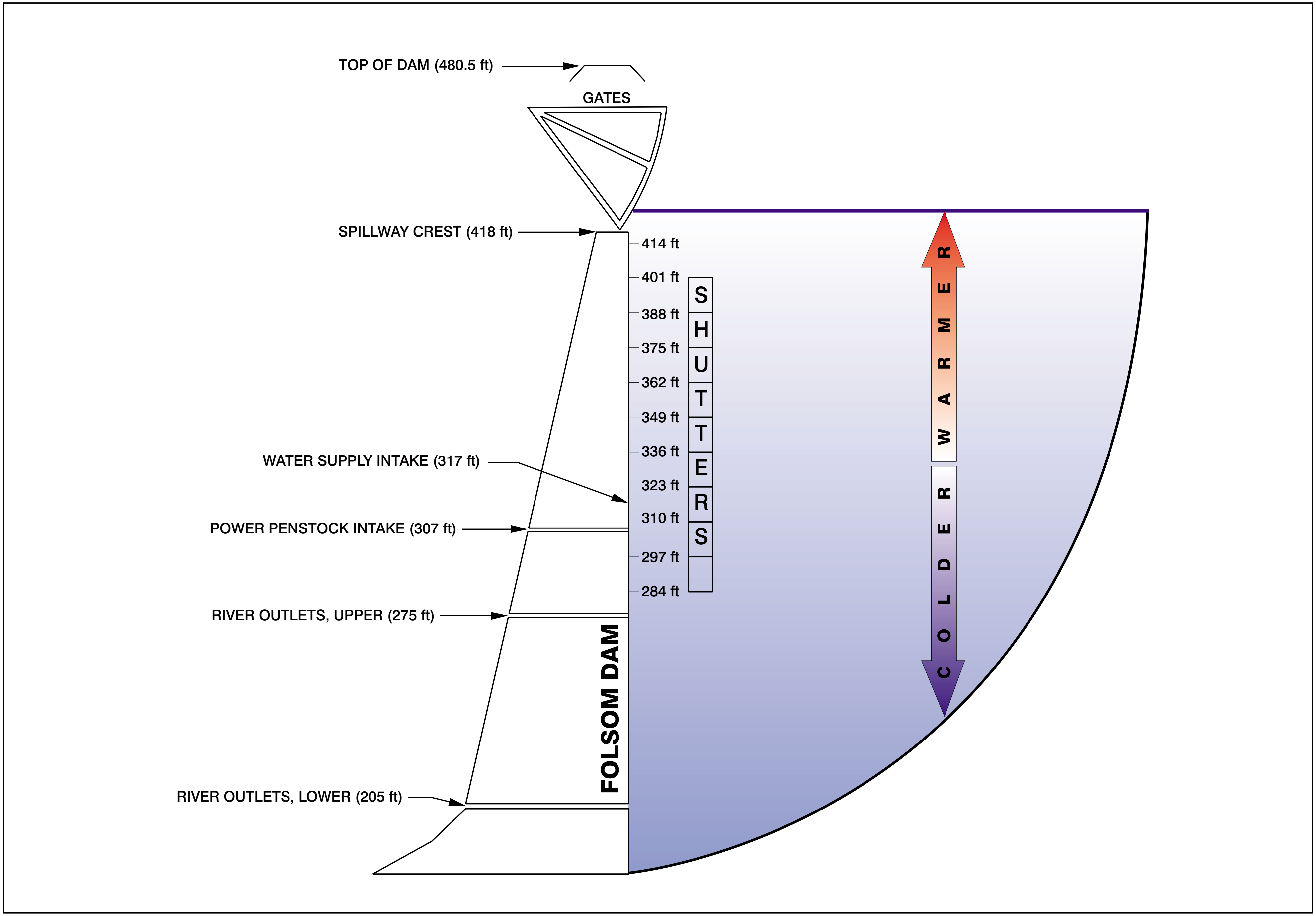
Each of the three power penstock intakes on Folsom Dam is enclosed in a housing that supports a set of removable shutter panels. Each penstock intake's housing supports a set of 45 panels assembled in five vertical sets of nine panels. Each panel is thirteen feet in height. The penstock intakes are located low inside the shutter assembly. Varying numbers of panels can be lifted up to draw in water at various elevations, thereby controlling the temperature of the water released from Folsom Dam. **Figure 1** illustrates the relative depths in Folsom reservoir of the temperature control device and shutters.

Folsom Dam shutter management allows some flexibility in the management of the cold-water pool. By operating the shutters to withdraw water from the highest available reservoir elevation during the winter and spring months, when water temperatures are suitably cold for fishery protection, the lowest reservoir elevation cold-water reserves can be conserved for later seasonal fishery protection benefits. During the thermal fishery protection seasons, generally summer and fall, the temperature control shutters are managed to withdraw from selective reservoir elevations in a manner which best matches the capabilities of the selective shutter options and fishery protection objectives.

Historically, the panels have been bolted together into two configurations: 1-1-7 and 3-2-4. Initially, in the 1-1-7 configuration, the top two panels could be raised individually, and the remaining seven lower panels were bolted together and could be raised only as a unit, after the top two panels were raised. However, in the 1995 Contract Between the United States of America and the Sacramento Area Flood Control Agency Concerning the Operation of Folsom Dam and Reservoir (Contract No. 5-07-20-X0322), SAFCA agreed to modify the shutters from the initial 1-1-7 configuration to the existing 3-2-4 configuration. In the existing 3-2-4 configuration, the top three panels are bolted together and can be raised as a unit. The next two panels are bolted together and can be raised as one unit after the top three panels are raised. Finally, the remaining four lower panels are bolted together, and can be raised as a unit after the upper five panels are raised. These configurations allowed for four distinct elevations from which the releases from Folsom Dam could be drawn. Units of shutter panels could be removed or replaced allowing for releases to be made without any panels in place, or with the lowest, or the two lowest, or all three units in place. The structure of the Folsom Dam shutter housing currently limits the number of shutter panel units of to three.

Shutter position changes at Folsom Dam are currently performed manually. A crew of three people, one to run the gantry crane trolley beam and hoist, one to check operations and signal the crane, and one to set latches, pull pins, etc., is required to change the shutter positions at Folsom Dam. The operation requires 8 to 12 hours and also interferes with traffic using the road over the dam. Because of the manual labor requirements and the need to schedule the traffic interruptions the current shutter configuration is only changed 3-4 times per year. Historically the shutter settings on all three penstocks have been set at the same withdrawal level. This allows for flexibility in scheduling releases through the penstocks for power generation and maintenance purposes.

Figure 1. Folsom Reservoir Temperatures



Shutter configurations that provide more flexibility over a wider range of Folsom Reservoir storage conditions allow for greater conservation of cold-water. Each time an additional unit of shutter panels is raised the release temperature immediately drops (because each subsequent unit is at a lower elevation). The greater the drop in elevation, the greater the drop in temperature. This often results in the release temperature being reduced to well below the target release temperature, thus depleting the cold-water pool more rapidly. As the cold-water pool is depleted, release temperatures gradually increase. A greater number of possible release elevations allow Folsom to be operated in such a way that the range of operational temperature variations is reduced and the desired temperature is more closely met. The narrowing of the temperature range reduces the period of time in which the water released is colder or warmer than the target temperature.

Under various hydrological and meteorological conditions, the different configurations of three shutter panel units allow for varying operations for controlling downstream temperatures by controlling release elevations. The 1-1-7 configuration allowed for careful selection of warm water from the surface of Folsom Reservoir, by providing multiple options at the top elevations when water surface elevations caused shutters to be raised to maintain hydraulic requirements. The 1-1-7 configuration did not serve fisheries protection objectives in summer months because the lowest unit had a large number of panels. If the hydraulic requirements forced the lowest unit to be raised in the summer, cold-water conservation for the fall was lost. The 3-2-4 configuration allows greater control throughout mid summer and fall months; however, carefully controlled surface selection of warm water is limited in wetter years.

Proposed Re-Operation Mitigation

A 1-1-2-2-3 configuration has been proposed as mitigation for the Folsom Re-Op. The structure of the shutter housing would have to be retrofitted to allow for five separate units of shutter panels. Such a configuration would allow for selection of six different release elevations instead of the historical two or four. The top two panels, each individually representing a unit, would allow selective withdrawal elevations identical to the historical 1-1-7 configuration. The next two units, each of two panels, would allow selective withdrawal elevations similar to that of the 3-2-4 configuration. This configuration would be operated manually, similarly to the existing configuration. The increase in flexibility of setting the level of reservoir releases allows more efficient use of the cold-water pool available in Folsom Reservoir.

Scenarios for Analysis

The exact physical and operational characteristics of potential modifications to the temperature control device at Folsom Dam were not known at the time of this evaluation. They could range from modifications to the existing structure to a completely new structure with infinite flexibility. The improvements are designed to give additional flexibility in setting the physical withdrawal level from the reservoir and additional flexibility in ability to change the withdrawal level.

For purposes of this evaluation the assumption was made that improvements in the ability to release from various levels in Folsom Reservoir would be made by using the existing shutter structure with modifications to allow each shutter to be raised and lowered individually. Because of flow limitations the bottom two shutters must be operated as a single unit. The resulting 1-1-1-1-1-1-1-2 or 7(1)-2 configuration would provide the greatest possible operational flexibility using the existing shutters, allowing the withdrawal level to be set at 13-foot intervals. This assumption allows use of existing modeling data and tools while providing almost the same amount of operational flexibility as a truly unlimited positioning scheme.

Improvements in the ability to reposition the shutters were assumed to result from the ability to re-position the shutters in a very short time interval as often as desired.

Four scenarios were selected for evaluation in this study:

1. Existing Condition - Current temperature control device and operations at Folsom Dam. (3-2-4)
2. Future Without-Project Condition - SAFCA proposed Folsom Re-Operation mitigation system. (1-1-2-2-3)
3. Project – Manually adjusted 7(1)–2
4. Mechanized Project – Mechanically adjusted 7(1)–2

Modeling Tools

There are a number of existing modeling tools available that were considered for use in this analysis. These tools are briefly summarized here.

PROSIM Model

The U. S. Bureau of Reclamation's (Reclamation's) PROSIM model simulates CVP and SWP operations and the hydrologic effects of those operations on the major Central Valley river and reservoir systems. The model simulates system operations within the geographical area affected by CVP and SWP facilities, including the Sacramento-San Joaquin Delta (Delta).

A network of 67 computation points, or nodes, represents river systems and project facilities. PROSIM uses a mass balance approach to simulate the occurrence, regulation, and movement of water from one node to another. At each node, various physical processes (e.g., surface water inflow or accretion, flow from another node, groundwater accretion or depletion, and diversion) can be simulated or assumed. Operational constraints, such as reservoir size and seasonal storage limits or minimum flow requirements, can be defined for each node. The model uses a monthly time step. Flows are specified as a mean flow for the month and reservoir storage volumes are specified as end-of-month content.

PROSIM simulates operations of the following water storage and conveyance facilities: Trinity, Whiskeytown, and Shasta/Keswick reservoirs (CVP); Spring Creek and Clear Creek tunnels (CVP); Oroville Reservoir (SWP); Folsom Reservoir and Natoma Reservoir (CVP); Tracy (CVP), Contra Costa (CVP), and Banks (SWP) pumping plants; San Luis Reservoir (shared by CVP and SWP); and East Branch and West Branch SWP reservoirs. To varying degrees, nodes also define conveyance facilities including the Tehama-Colusa, Corning, Folsom-South, Delta-Mendota, and California Aqueduct canals.

Other water systems tributary to the Delta are modeled separately from PROSIM and are incorporated as a known input at a PROSIM node. These tributaries are the San Joaquin River, the New Melones/Stanislaus River system and the East Side streams, consisting of the Cosumnes River, Mokelumne River, Calaveras River and several smaller creeks. These river systems are simulated by a combination of Reclamation models, SANJASM and STANMOD.

The model simulates one month of operation at a time, sequentially from one month to the next, and from one year to the next. Each decision that the model makes regarding stream flow regulation is the result of defined operational requirements and constraints (e.g., flood control storage limitations, minimum instream flow requirements, Delta outflow requirements, diversion requirements) or operational rules (e.g., preference among reservoirs for releasing water). Certain decisions, such as the definition of water year type, are triggered once a year, which leads to water delivery allocations and specific stream flow requirements. Other decisions, such as specific Delta outflow requirements, are dynamic from month-to-month.

PROSIM operates Shasta and Folsom reservoirs by releasing water to satisfy instream flow and downstream diversion requirements north of the Delta while observing requirements for minimum storage and flood control capacity. PROSIM then identifies demands for diversion and storage south of the Delta. Next, with preliminary estimates of Delta inflows and export demands, PROSIM calculates the flow required to satisfy all Delta water quality requirements. The obligation to satisfy Delta requirements is shared between the CVP and SWP based on the terms of the Coordinated Operating Agreement (COA). CVP reservoir releases for Delta requirements are balanced between Trinity, Shasta and Folsom reservoirs.

Technical Appendix Volume Seven of the Draft Programmatic Environmental Impact Statement (PEIS) for the Central Valley Project Improvement Act (CVPIA) provides documentation of PROSIM, SANJASM, and STANMOD as utilized in that study. Modifications have been incorporated by Reclamation in the PROSIM code and data sets subsequent to that effort. PROSIM Version 2000 was used in this study.

Automated Temperature Selection Procedure (ATSP)

This procedure operates the Folsom Reservoir and LAR models in an iterative manner referred to as the Automated Temperature Selection Procedure, with the objective of achieving monthly target temperatures in the LAR at Watt Avenue. Targets are achieved through choice of reservoir level from which the release is drawn.

A schedule of temperatures, for each month of the year, is specified as the preferred schedule of monthly temperature targets. Each year of the simulation, the model attempts to meet the preferred schedule of temperatures. If the preferred schedule cannot be met, the procedure cycles to a second, slightly less preferred schedule of temperatures. If the second schedule cannot be met, the procedure continues through a series of schedules, arranged by declining preference, until a schedule of targets is met for that year. Specification of the schedules enables the model user to regulate management of the Folsom Reservoir cold-water availability for a desired temperature regime in the river, altering seasonal priorities for various hydrologic/meteorological conditions.In this way, the ATSP can be used with the models to mimic in the temperature analysis, the implementation of Optimal Cold-water Pool Management that the Lower American Operations Workgroup strives to accomplish.

Seasonal Priorities/ATSP Schedules

The ATSP involves the use of multiple target temperature schedules for the LAR at Watt Avenue. The “schedule” approach was developed with the purpose of balancing the seasonal use of Folsom Reservoir’s cold-water availability, which varies from year to year. **Table 1** summarizes the target Watt Avenue temperature for the schedules.

Schedule #1 is the most beneficial application of cold-water for conditions when sufficient cold-water releases can be made from Folsom Reservoir. Schedule #48 is the least desirable for fisheries benefits, but requires much less cold-water to be released from Folsom Reservoir during the summer months, relative to other schedules. The May through November targets are varied incrementally, to reduce and shift the amount of cold-water released during the summer months, to achieve the species balance objectives. There are no targets for the months of January – April, or December. During this time of the year Folsom Reservoir is usually quite cold and very well mixed. Since the reservoir is already quite cold and the temperature does not vary as much with the depth target temperatures are not met during this period.

Reservoir and River Temperature Model

Reclamation has developed water temperature models for five reservoirs (Trinity, Whiskeytown, Shasta, Oroville, and Folsom) and three river systems (Sacramento, Feather, and American). The models for reservoirs are distinctly different than the models for rivers. Because of the monthly time step and relatively small reservoir volumes, regulating reservoirs (Lewiston, Keswick, Thermalito, and Natoma) are

Table 1. ATSP Target Temperature Schedules

Schedule	May	Jun	Jul	Aug	Sep	Oct	Nov
1	56	56.5	65	65	65	57	55
2	57	57.5	66	66	66	57	55
3	58	58.5	66	66	66	57	55
4	59	59.5	66	66	66	57.3	55
5	59	60.5	66	66	66	57.3	55
6	59	61.5	66	66	66	57.3	55.5
7	59	62.5	66	66	66	57.3	55.5
8	59	63.5	67	67	67	57.3	55.5
9	60	63.5	67	67	67	57.3	55.5
10	60	63.5	67	67	67	57.8	56
11	60	64	67	67	67	57.8	56
12	61	64	67	67	67	57.8	56
13	61	64.5	67.5	67.5	67.5	57.8	56
14	61	65	67.5	67.5	67.5	57.8	56
15	62	65	67.5	67.5	67.5	57.8	56
16	62	65.5	67.5	67.5	67.5	57.8	56
17	63	65.5	67.5	67.5	67.5	58.0	56
18	64	65.5	67.5	67.5	67.5	58.0	56
19	64	65.5	68	67.5	67.5	58.0	56
20	64	65.5	68	68	68	58.3	56
21	64	65.5	68	68	68	58.8	56
22	64	66	68	68	68	58.8	56.5
23	64	66.5	68	68	68	58.8	56.5
24	65	66.5	68	68	68	58.8	56.5
25	65	66.5	68	68	68	59.3	56.5
26	65	66.5	68	68	68	59.3	56.8
27	65	67	68	68	68	59.3	56.8
28	65	67	68	68	68	59.5	56.8
29	66	67	68	68	68	59.5	56.8
30	66	67	68	68	68	60	57.1
31	66	67	69	68	68	60	57.1
32	66	67	69	69	69	60	57.1
33	66	67.5	69	69	69	60	57.1
34	67	68	69	69	69	60.8	57.1
35	67	68.5	69	69	69	60.8	57.1
36	67	68.5	69	69	69	61.3	57.1
37	67	68.5	69	69	69	61.3	57.4
38	68	68.5	69	69	69	61.8	57.4
39	68	68.5	69	69	69	61.8	57.7
40	68	68.5	70	69	69	61.8	57.7
41	68	68.5	70	70	70	61.8	57.7
42	68	69	70	70	70	61.8	57.7
43	68	69	70	70	70	61.8	58
44	68	69.5	70	70	70	62.5	58
45	69	69.5	70	70	70	62.5	58
46	69	69.5	70	70	70	63	58
47	69	69.5	70	70	70	63	58.3
48	69	69.5	71	70	70	63	58.3

modeled similar to river reaches rather than as storage reservoirs. These models are used to identify changes in water temperature caused by changes in CVP/SWP operations. They estimate mean monthly water temperatures based on monthly flow and storage quantities. Reclamation's temperature models were documented in U.S. Bureau of Reclamation Monthly Temperature Model Sacramento River Basin, June 1990 and Technical Appendix Volume Nine of the Central Valley Project Improvement Act (CVPIA) Programmatic Environmental Impact Statement. Subsequent inevitable modifications have been incorporated into the model by Reclamation as new information regarding input data, operational procedures, facility modifications, and calculation techniques become available; the reader is referred to Reclamation for further information regarding those modifications.

The ATSP uses the Folsom Reservoir and Lower American River Temperature models. These models are used to identify changes in water temperature caused by changes in Folsom operations. Reservoir inflow, outflow and end-of-month storage content are input to the reservoir temperature model. Additional input data include meteorological information (evaporation, precipitation, solar radiation, and monthly air temperature), and monthly temperature targets which are used by the model to select the level from which reservoir releases are drawn.

The Folsom Reservoir Temperature Model is a one-dimensional reservoir model in which a vertical water temperature profile in the reservoir is simulated based on inflow and outflow water temperature and flow rate, monthly storage content, and meteorological information. The temperature control device is incorporated in the simulation. The model output includes water temperature at each level in the reservoir as well as temperature of the reservoir release. The LAR temperature model inputs include the calculated temperature of Folsom Reservoir release, much of the same meteorological data used in the reservoir model, and PROSIM output on river flow rates, gains and diversions. Model output includes mean monthly water temperatures calculated at multiple locations on the American rivers.

Cold-Water Pool Management Model (CPMM)

The CPMM was originally developed by Surface Water Resources, Inc. (SWRI) as mitigation for potential increases in already stressfully high July to September river temperatures as a result of implementing Reclamation's water supply contracts with the Sacramento County Water Agency, City of Folsom, and San Juan Water District (P.L. 101-514). The CPMM provides a tool that can be used to improve management of LAR temperatures to benefit steelhead and fall-run chinook salmon by tailoring Folsom Dam shutter operations to annual hydrologic and meteorological conditions.

The CPMM can be used to either "optimize" Folsom shutter operations for a given year or to develop operations that avoid (or minimize) temperature-related impacts due to an change in conditions. The CPMM is used to select the most beneficial seasonal target water temperature objectives for the LAR during a given year and the operational plan to obtain the selected temperature objectives. Selection of seasonal temperature objectives is characterized by the rate and duration with which cold water must be released from Folsom Reservoir to control river temperatures. This is based on the biological benefit expected from controlling LAR temperatures, and is limited by the amount of cold water available in Folsom Reservoir.

The analysis process used to select temperature objectives for the LAR and the desired operational plan involves two steps. Initially, the model user determines the most beneficial, reasonably achievable LAR water temperatures at Watt Avenue, assuming that releases are not constrained by either Folsom shutter operation constraints or hydropower operation constraints. Once the temperature objectives are selected, the model user can apply shutter and hydropower operations constraints in an iterative process to select an operational plan that accomplishes the water temperature objectives. The result is a cold-water pool management plan that can be implemented and which maximizes temperature benefits to LAR salmonids within hydrologic and operational constraints.

The CPMM provides the user guidance in selecting a suitable schedule of temperature targets for the LAR that, if achieved, balance fisheries needs throughout the year. The best schedule is selected for a given year, based on cold-water pool volume and other operational constraints. Based on this schedule, an operational plan to achieve the schedule's temperature objectives is developed.

Components of CPMM

The CPMM includes three components, an Input/Output User Interface, a Folsom Reservoir Temperature Model, and a Lower American River Temperature Model.

The input/output user interface is a Lotus 123 spreadsheet, *CPMM.123*. The user interface allows for the specification of all initialization data; input of forecasted time-series data and reservoir and river description data; integration of the reservoir temperature model and the riverine temperature model; parameter estimation for the riverine temperature model; and production of summary and detailed graphical outputs. Data pre-processing, the reservoir temperature model simulations and data post-processing are performed in DOS executables called from the *CPMM.123* spreadsheet.

The reservoir temperature model is a modified version of the Army Corps of Engineers Waterways Experiment Station's (CEWES) CE-THERM-R1 model. The model calibration used was developed by J. Humphrey and W. Blood for the Sacramento Area Flood Control Agency (SAFCA) in support of SAFCA's Interim Folsom Re-Operation. Model source code modifications made by J. Humphrey and W. Blood were also included. Modifications by SWRI include the addition of a customized outlet/shutter selection routine, water supply intake operations routine, and additional inputs/outputs. This model uses weekly time step inputs/output but internally computes the reservoir temperature profile on a daily basis.

The riverine temperature model is an equilibrium temperature model similar to the Reclamation model developed by J. Rowell (Reclamation). Parameter estimation for the equilibrium temperature model and the model itself are integrated into the *CPMM.123* spreadsheet.

Salmon Mortality Models

Water temperatures calculated for specific reaches of the Sacramento and American rivers are used in Reclamation's chinook salmon mortality models to estimate annual percentage mortality of early-life-stage chinook salmon. The models incorporate expected timing and spatial distribution of spawning in the respective river reaches, based on CA Department of Fish and Game (Water and Aquatic Habitat Conservation Branch) data from on going monitoring using aerial redd surveys and spawning stock escapement estimates during the past 10 years.

The salmon mortality models are described in Appendix B, Technical Appendix on Modeling for SAFCA Long-Term Operation of Folsom Reservoir. Output from the salmon mortality models provided estimates of annual (rather than monthly mean) losses of emergent fry from egg potential (all eggs brought to the river by spawning adults), which is presented in terms of survival.

Application of Modeling Output

The models are tools that have been developed for comparative planning purposes, not for predicting actual river conditions at specific locations at specific times. Reservoir storage, river flows, water temperature, and salmon survival output for the period modeled should not be interpreted or used as definitive absolutes depicting actual river conditions that will occur in the future.

The models used, although mathematically precise, should be viewed as having "reasonable detection limits." Establishing reasonable detection limits is useful to those using the modeling output for impact assessment purposes, and prevents making inferences beyond the capabilities of the models and beyond an ability to actually measure changes. Although data from the models are output to the nearest 100 acre-feet, tenth of a foot in elevation, tenth of a CFS, tenth of a degree Fahrenheit, and tenth of a percent in salmon mortality, these values were rounded when interpreting differences for a given parameter between two modeling simulations. For example, two simulations having river flows at a given location within one percent of each other were considered to be essentially equivalent. Because the models provide reservoir storage data on a monthly time-step, measurable differences in reservoir storage were evaluated similarly. Similar rounding of modeled output was performed for other output parameters in order to assure the reasonableness of the impact assessments. Because of their importance regarding assessing impacts to listed and proposed-listed salmonid resources, definition of measurable differences in modeled temperatures and salmon mortality is discussed in greater detail below.

Commonly used field-temperature monitoring equipment (in situ temperature loggers, thermometers, electronic meters) have a total error of measurement of 0.2°F or more. Thus, modeled differences in temperature of 0.2°F or less could not be consistently detected in the river by actual monitoring of water temperatures. In addition, as mentioned above, output from Reclamation's river temperature models provides a "relative index" of water temperatures under the various operational conditions modeled. Output values indicate whether the temperatures would be expected to increase, remain unchanged, or decrease, and provide insight regarding the relative magnitude of potential changes under one operational condition compared to another.

Typically, for the purposes of impact assessment, temperature changes within 0.3°F between modeled simulations are considered to represent no measurable change. Temperature differences of more than 0.3°F are assessed for their biological significance. This approach is very conservative (rigorous). For example, the U.S. Fish and Wildlife Service (USFWS) and Reclamation, in the Trinity River Mainstem Fishery Restoration Draft Environmental Impact Statement/Environmental Impact Report (USFWS et al. 1999), used a change in long-term average water temperature of 0.5°F as a threshold of significance, and the Central Valley Regional Water Quality Control Board generally uses a change of 1.0°F or more as a threshold of significance.

Since an accurate biological measure of success does not exist, there are no absolutes with respect to actual river conditions post project. Therefore, success in improving LAR temperature conditions is measured comparatively. Water temperatures in the LAR are frequently higher than desired during the summer and fall periods. In Lower American River Temperature Improvement Study Function Analysis Report, the temperature device is acknowledged as a readily implementable means of controlling temperatures within the bounds of available cold water supply. To the extent that the shutter modifications facilitate avoidance of extreme LAR water temperatures fluctuations and/or make it possible distribute the limited cold-water resource for sharing between the steelhead and Chinook salmon better than is possible today, success is affirmed.

Modeling Procedure Development

In order to proceed with modeling a number of assumptions had to be made. These assumptions are listed below:

<u>Physical Assumptions:</u>

- Maintain existing 9 shutter physical system with 13’ tall shutters. This assumption is built into all the existing Folsom Reservoir temperature models.

- Require a 26’ opening for withdrawal based on flow requirements for the penstocks.

- Require a minimum of 2 shutters (26') down, or all shutters up. It is not possible to have just one shutter down because of flow limitations at the penstock intakes.

- Maintain the historical Reclamation practice of having the shutter settings at the same level at all three penstocks.

Operational Assumptions

- Manual shutter adjustments are only made within a year to raise the shutters, or lower the temperature. All shutters are assumed to be lowered during the winter months in preparation for the next year. This is the typical Reclamation historical operation.

- Manual adjustments cannot be made more often than once every two weeks.

Model Selection

None of the models listed above are perfectly suited for the present analysis. To evaluate the wide range of hydrologic conditions that occur in the American River Basin, it would be ideal to perform model studies that encompasses the entire 70-year period of record. Such requirements would suggest that a combination of Reclamation's PROSIM model and Folsom Reservoir and American River water temperature models with the ATSP be used. However, the monthly time-step of these models precluded the shorter time-step analysis necessary for the 7(1) - 2 alternative, in which the shutter positions would be adjusted more often than once a month.

CPMM, on the other hand, allows the shutter adjustment to occur as frequently weekly. However, it has the disadvantage of simulating only one year. Nonetheless, because the purpose of the analysis is to evaluate the benefits of being able to adjust the shutter settings more frequently than once a month, the CPMM was selected for this analysis.

To gain a better understanding of the results under different hydrologic conditions, three weekly time interval data sets were developed to represent years with favorable, moderate, and adverse hydrologic/meteorological conditions for temperature management purposes.

Modeling Data Development

Due to the short time frame for the analysis the decision was made to use existing ATSP and PROSIM simulations as a guideline for development of the weekly input data required for CPMM model for each of the three year types to be analyzed. This also provides a level of consistency between previous work and this analysis.

Existing ATSP runs with the 3-2-4, 1-1-2-2-3, and 7(1)-2 configurations based on a PROSIM existing condition with 400-600 flood control simulation study were selected as a data source for this project.

A number of years representative of those with favorable, moderate, and adverse ATSP temperature schedules were selected. From these representative years we compiled the mean monthly values for a number of variables required by the CPMM model. These variables include:

- Total Inflow
- Inflow Temperature
- Total Release
- Air Temperature
- Lower American River gains
- Folsom Water Supply Diversion
- Carmichael Diversions
- Sacramento City Filtration Plant diversions
- Initial Folsom Reservoir Temperature Profiles

This data was then converted to approximate weekly values while maintaining the monthly totals. All monthly data was converted to weekly data by fitting a curve to the 12 monthly values and interpolating on the curve for the 52 weekly values. The total inflow and inflow temperature were disaggregated to North and South Fork inflow and inflow temperature by applying the percent contribution for each river fork source obtained in 1997 to the representative year weekly volume. For example, the weekly contribution to Folsom inflow from the north, middle, and south forks of the American River is not known for all years. However, these weekly contributions have been assessed for 1997. Therefore, for the years being investigated, the relative contribution by each river fork source was obtained by applying the percent contribution for each river fork source obtained in 1997 to the representative year total weekly volume. Similarly, inflow temperature data was disaggregated using the 1997 temporal distribution.

Meteorological conditions such as wind speed, cloud cover, humidity, air pressure were assumed to be constant 1997 values from the CPMM model for all year types.

Model Modifications

The CE-THERM-R1 model was modified by SWRI to operate in two modes: automatic and manual. In either mode, the model user inputs the available shutter configurations, sorted from the highest to lowest elevation (and therefore temperature), and weekly target temperatures at Watt Avenue for the year. In the automatic mode the model selects the elevation from which water will be withdrawn each day so that the target temperature at Watt Avenue is not violated. This is done by first computing the Folsom release temperature that corresponds to the Watt Avenue target temperature for the week. Then, beginning with the shutter configuration with the highest temperature the model checks to see if the configured opening can be used based on reservoir elevation. If the configuration is usable then the release temperature is computed based on the computed reservoir temperature profile and the current shutter figuration and compared to the computed desired release temperature. If the configuration is unusable or the computed temperature is greater than the desired temperature the next coldest shutter configuration is evaluated until a shutter configuration is found that meets the target or there are no more configurations. In manual mode the user inputs the shutter configuration to be used each week. The model then uses this configuration each day of the week to compute the release temperature. The release temperature is then used in the river model portion of the CPMM to compute the Watt Avenue river temperature.

The Salmon Mortality model also required some modifications. The model reads it's input data as mean monthly values. Internally the model computes a number of mortality factors on a daily basis. The internal daily values are computed from the monthly mean values using a linear interpolation. In this analysis our temperatures are allowed to vary on a weekly basis. The conversion of mean monthly values to daily values loses this variability in the mortality computations. **Figure 2** shows this problem graphically. For this analysis the mortality model was modified to read in the weekly temperatures from the temperature modeling and use these values for each day of that week in the daily computations.

Figure 2. Salmon Mortality Model Temperature Input

Analysis Procedure

A set of possible shutter configurations sorted from the highest release temperature or highest elevation to the lowest was developed for each potential shutter configuration. **Table 2** shows the withdrawal elevations (centerline of opening) possible for each shutter configuration.

Table 2. Possible Withdrawal Elevation for Each Shutter Configuration

	Shutter Configuration		
	3-2-4	**1-1-2-2-3**	**1-1-1-1-1-1-1-2**
All Gangs Down	414	414	414
1 Gang Up	375	401	401
2 Gangs Up	349	388	388
3 Gangs Up	297	362	375
4 Gangs Up	-	336	362
5 Gangs Up	-	297	349
6 Gangs Up	-	-	336
7 Gangs Up	-	-	323
8 Gangs Up	-	-	297

There are basic assumptions in each of the 12 simulations to be performed are summarized in **Table 3**.

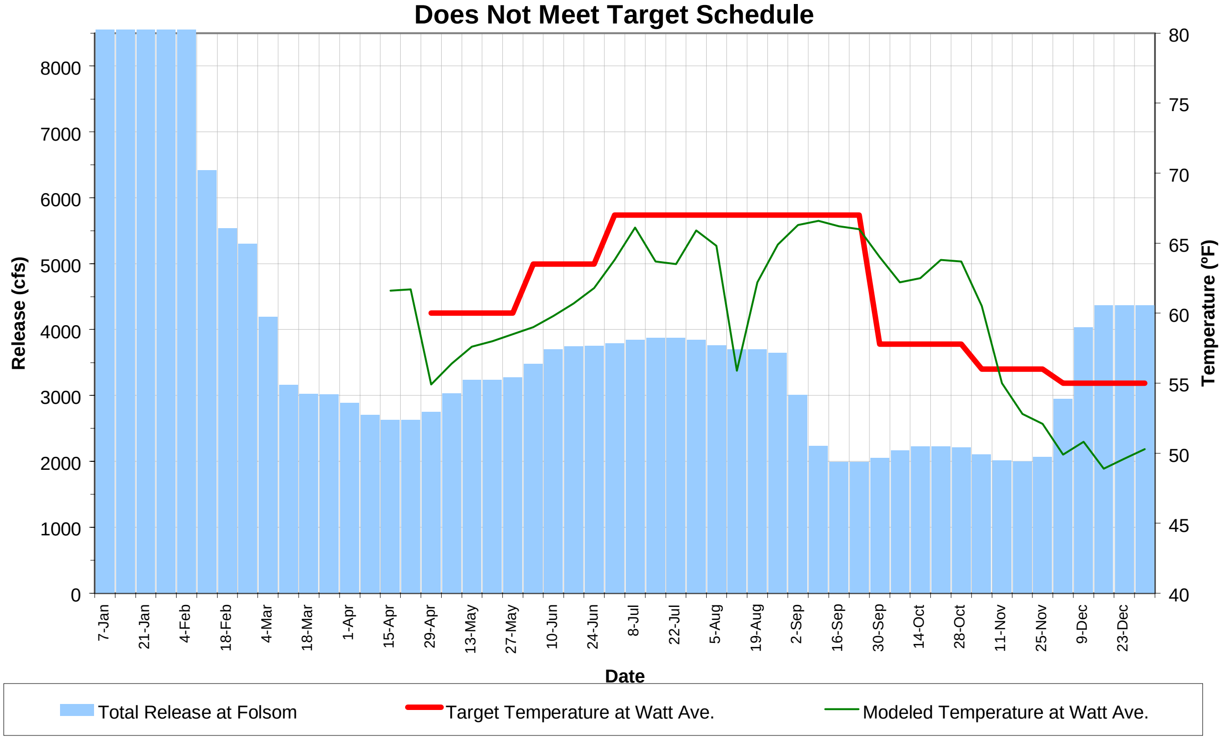
Table 3. Simulation Assumptions

Simulation	Alternative	Shutter Configuration	Year Type	Adjustment Type
1	Existing	3-2-4	Favorable	Manual
2	Existing	3-2-4	Moderate	Manual
3	Existing	3-2-4	Adverse	Manual
4	Future Without-Project	1-1-2-2-3	Favorable	Manual
5	Future Without-Project	1-1-2-2-3	Moderate	Manual
6	Future Without-Project	1-1-2-2-3	Adverse	Manual
7	Project	7(1)-2	Favorable	Manual
8	Project	7(1)-2	Moderate	Manual
9	Project	7(1)-2	Adverse	Manual
10	Mechanized Project	7(1)-2	Favorable	Mechanized
11	Mechanized Project	7(1)-2	Moderate	Mechanized
12	Mechanized Project	7(1)-2	Adverse	Mechanized

The analysis procedure consists of selecting a trial temperature schedule and running the CPMM model in automatic mode. The results of this simulation are examined ensure that the target temperatures in the chosen schedule have been met. If the targets are met then a "better" schedule is selected for the next trial. If, on the other hand, the target temperatures are not met then a "worse" schedule is selected.

Figure 3 shows the results of a single CPMM simulation. As can be seen in this figure, the shutter configuration for this trial requires that so much cold water be released in the summer months that there is not sufficient cold water to meet the temperature targets in the fall. This result indicates that a "worse" schedule needs to be attempted. Figure 4 is an example of the results of a CPMM simulation in which the target temperature schedule was met. Note that this is not necessarily the "best" schedule only that this schedule can be met.

Figure 3. Example Temperature Simulation Does Not Meet Target Schedule



This process is repeated until the "best" target schedule found. This results in the selection of the "best" target temperature schedule that could be met given the assumed conditions and allowing daily shutter adjustments. Since the schedules are ranked on an annual, multi species balanced, biological basis, this "best" target schedule is assumed to be the most biologically favorable shutter operation.

Once the "best" schedule is found, the CPMM model is run in manual mode with the daily shutter adjustments from the automated simulation being imposed weekly rather than daily. Limiting the frequency of shutter adjustments result in changes in computed release temperature, and thus a violation of the target temperature. Consequently, the process of finding the "best" schedule may need to be repeated in manual mode. For the mechanized simulations 10, 11, and 12 the automated trial is the final simulation.

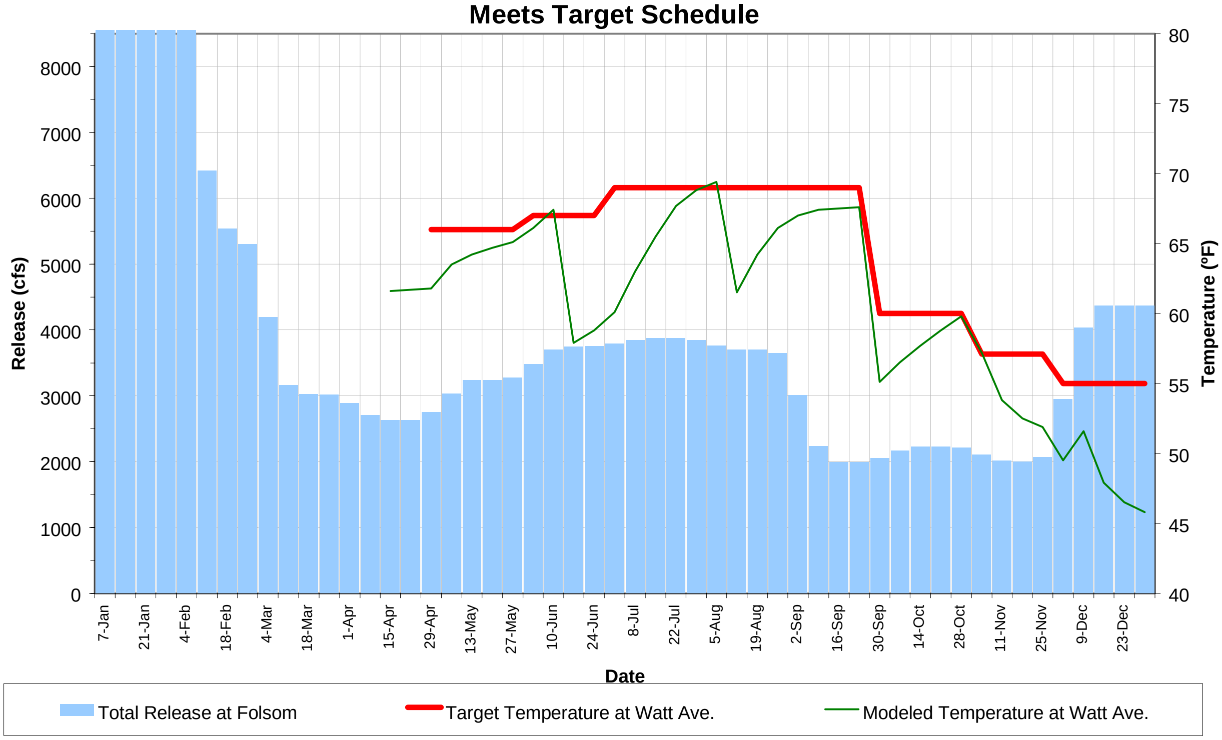
The temperature results from the 12 final simulations were then used as input to the salmon mortality model.

Verification

Although the analysis process presented here is similar to the existing ATSP process, the results are not directly comparable to those of the ATSP analysis. There are a number of reasons for the differences, among which are the different time step and reservoir temperature model used. The most important reason, however, is the assumption, in this analysis, that the shutters at the three penstocks are set at the same level. This is unlike the ATSP, which allows blending of water from different depths in the reservoir. By allowing the blending of colder water with warmer water (i.e., taking water from different elevations), it is possible to take just enough cold water to cool down water taken from a higher elevation.

The blending of water from different depths is particularly favorable to the 3-2-4 configuration, resulting in a much lower temperature schedule than that achieved if the penstock intakes are set at the same level. The requirement that the shutters associated with all the penstocks are at the same level results in a dramatic drops in release temperature when the shutters are adjusted. The resulting release is often far colder than is required to meet the temperature target. This drop in temperature can be clearly seen in **Figure 4** at week 17-June.

**Figure 4. Example Temperature Simulation
Meets Target Schedule**



To verify that the poorer performance of the 3-2-4 configuration was indeed a result of the assumption that all penstock intakes be set at the same elevation, the 3-2-4 simulation was repeated using this modeling procedure and assuming that the shutters could be at different configurations for each penstock. The results of this test are much closer to the ATSP results. Based on this evaluation the process was accepted as working correctly.

Temperature Modeling Results

Table 4 is a summary of the final selected "best" schedules from each of the simulations. As can be seen from this table the selected schedules in each of the year types get better as we move from the 3-2-4 to the 1-1-2-2-3 to the 7(1)-2 Manual configurations. This tends to confirm increased that flexibility in withdrawal level results in improved temperature management in the LAR.

Table 4. Final Selected Schedules

	Existing (3-2-4)	Future Without-Project Condition (1-1-2-2-3)	Project (7(1)-2)	Mechanized (7(1)-2)
Favorable	39	30	20	20
Typical	32	29	23	23
Adverse	48	48	34	34

The 3-2-4 configuration does not show the expected pattern of results between the year types. The model output show that the Favorable year simulation results in a "worse" temperature schedule being selected than the Typical year simulation. **Figure 5** presents the result of the Favorable year simulation under the 3-2-4 configuration. As can be seen in this figure, releases from Folsom Reservoir increase just as the first gang of shutters are raised in the week of 17-June. This results in a large release of cold water from the reservoir that severely limits the ability to meet temperature targets throughout the rest of the year. The weekly release patterns developed for the Adverse and the Typical years do not show the same increase in Folsom releases. Consequently, the cold water pool is not depleted unnecessarily. The same problem does not occur in the other shutter configurations because they offer enough flexibility in withdrawal elevation to avoid large cold water releases during the same high release period.

Figures 6, 7, and 8 show the final modeled weekly temperatures for each shutter configuration for the Favorable, Typical and Adverse year types respectively. These figures demonstrate that as the operational flexibility increases, temperature fluctuations decrease. This change allows for a more efficient seasonal operation and results in better biological conditions in the system.

The 7(1)-2 Mechanical simulations show the same temperature schedule as the corresponding 7(1)-2 Manual simulations (Table 4). The modeled temperatures, however, are slightly different, usually lower. This implies that there is some temperature or biological benefit from the increased flexibility to change the withdrawal level.

Figure 5. Existing Condition (3-2-4)
Favorable Year Simulation Result

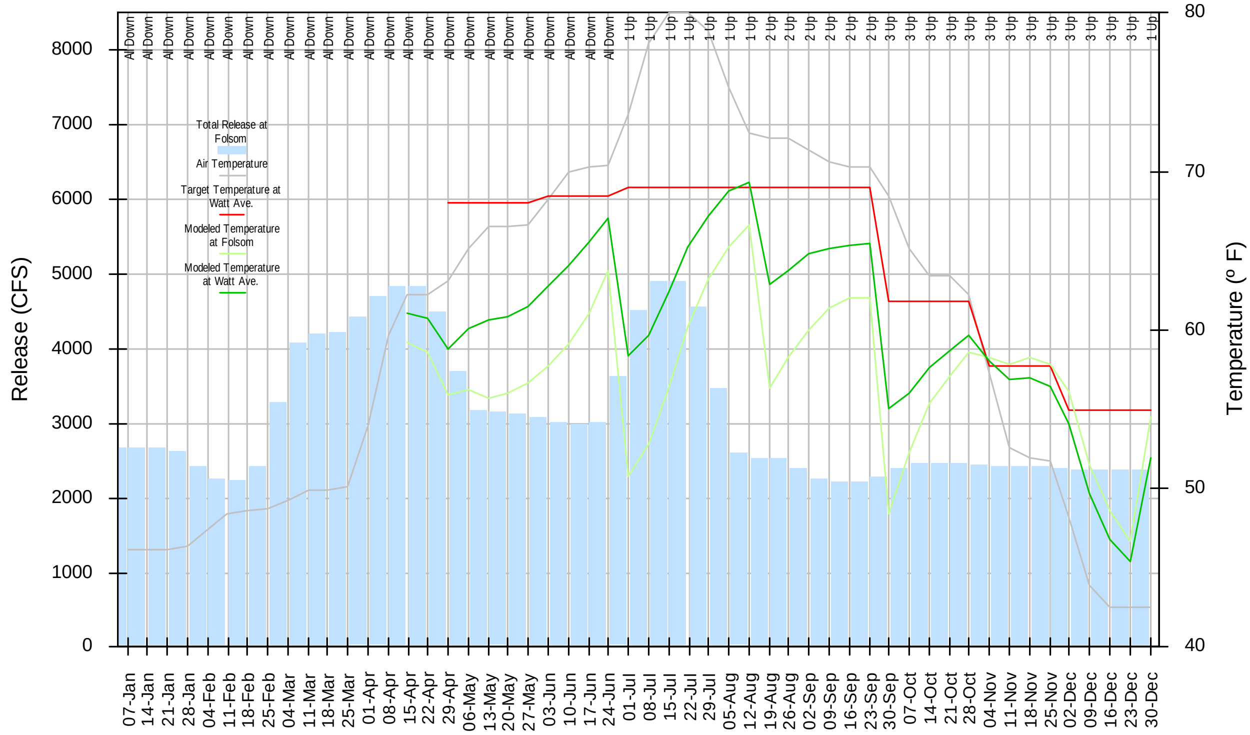


Figure 6. Favorable Year Modeled Watt Avenue Temperature

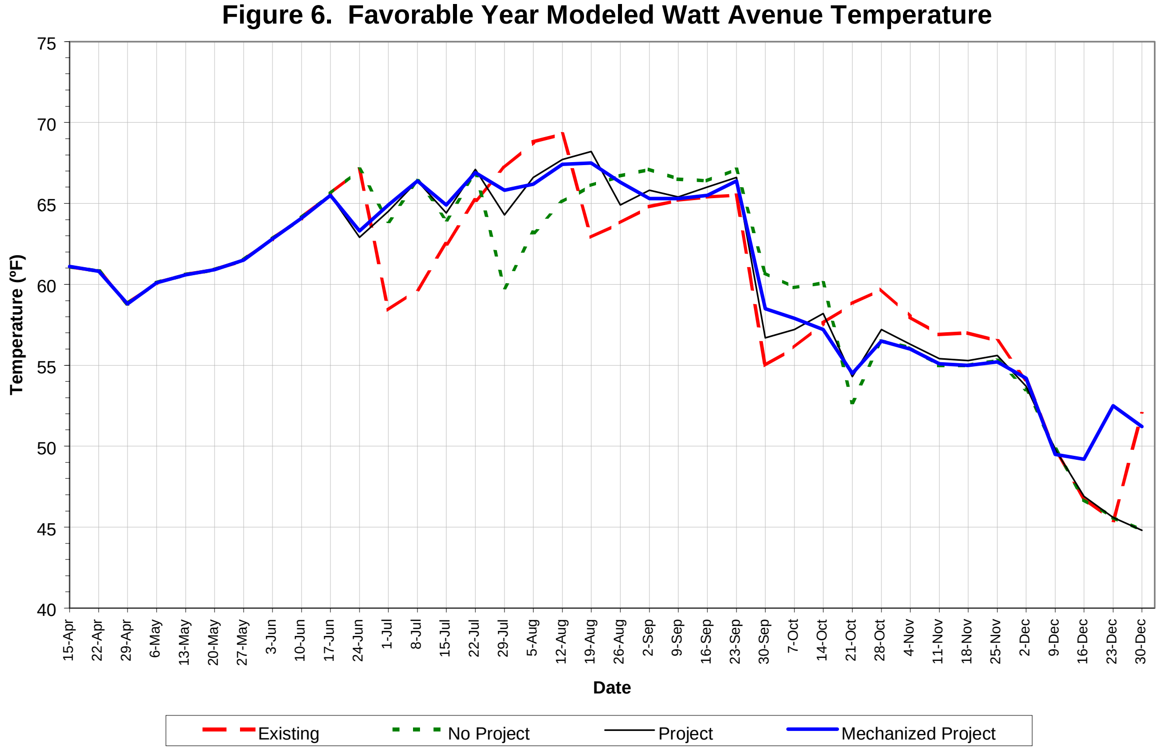


Figure 7. Moderate Year Modeled Watt Avenue Temperature

Figure 8. Adverse Year Modeled Watt Avenue Temperature

There are a number of benefits to a mechanized 7(1)-2 that cannot be captured in the modeling. These include:

- Because of the heating in the LAR, specific temperature targets at Watt Avenue require colder Folsom release temperature. Since this change in temperature along the river is less with higher flows a sudden increase in release from Folsom reservoir, such as a sudden change in Delta requirements, would allow warmer temperature water to be released from Folsom Reservoir to meet the same temperature at Watt Avenue. If the shutters could rapidly be adjusted it would conserve cold water in Folsom for use later in the year when it has a higher biological value.

- Would allow for a "real time" type temperature operation where river temperature could be optimized based on the actual fishery needs in the river instead of basing the temperature requirements on an expected schedule that the fish may or may not follow.

- Would allow for rapid response to power generation opportunities while still meeting temperature requirements. Folsom power releases are typically made for peaking purposes which vary on an hourly basis. Manual shutter adjustments are simply too slow to react on this time-scale.

Table 5 summarizes the results of the Salmon Mortality modeling. It is important to remember that these values are for salmon only and the modeling was done to identify the "best" year around balance between salmon and steelhead. These values do not identify the most beneficial solution by themselves. The values do follow the expected trends, that is lower mortality in more favorable years and lower mortality as flexibility increases over the alternative. The data shows the same problems with the 3-2-4 configuration as discussed in the analysis of selected schedules and for the same reasons.

Table 5. Annual Salmon Mortality (%)

	Existing (3-2-4)	Future Without-Project (1-1-2-2-3)	Project (7(1)-2)	Mechanized (7(1)-2)
Favorable	14.29	8.69	5.92	5.17
Moderate	10.13	11.87	6.07	6.55
Adverse	16.17	19.99	13.60	8.97

Potential Modeling Improvements

The largest single improvement that could be made to the modeling would be to use the traditional 70-year hydrologic modeling period instead of typical years. As discussed above the 3-2-4 configuration did not perform as expected in the selected Favorable year type because of the specific Folsom release pattern developed for that year. Use of the full 70-year hydrologic modeling period would give many more years of all types allowing a better analysis over the range of Folsom operations that could be expected.

Other improvements that could be made include:

- Use historical data to aid in splitting the monthly ATSP data into required weekly data; and
- Compare results of ATSP with this process used in as similar a manner as possible.

Lower American River Fishery Impact Analysis

The LAR is identified as habitat for two species of concern: steelhead and fall-run chinook salmon. The National Marine Fisheries Service (NMFS) has issued a one-year Biological Opinion for operation of the CVP, which includes an objective not to exceed a mid-day water temperature of 65˚F at Watt Avenue in the LAR for maintenance of steelhead habitat. In addition, surveys conducted by the California Department of Fish and Game (CDFG) over the last 10 years show that the fall-run chinook salmon do not begin spawning until temperature decrease to 60˚F or less during the fall (i.e., October or November). Also, numerous laboratory studies conducted throughout the West Coast show that chinook salmon embryo incubation success declines when constant water temperatures increase above 56˚F. Therefore, index temperatures for the LAR at Watt Avenue are 65˚F or less for all lifestages of steelhead, 60˚F or less for fall run chinook salmon spawning, and 56˚F or less for chinook salmon embryo incubation. The purpose of this evaluation is to assess how Watt Avenue temperatures associated with proposed Folsom Dam temperature control device shutter configuration modifications conform to the identified index temperatures for each specific lifestage of species of concern in the LAR.

The Folsom Dam shutter configurations analyzed are, as previously described, existing condition (3-2-4 shutter configuration), future without-project condition (1-1-2-2-3 shutter configuration), project condition (manual 7(1)-2 shutter configuration), and mechanized project condition (mechanized 7(1)-2 shutter configuration).

The period included for analyzing and comparing the different shutter configurations, as previously described extends from April 15 to December 30 during representative years of favorable, moderate and adverse conditions. This period encompasses several lifestages of fall-run chinook salmon and steelhead that would be potentially affected by water temperatures. The period of April 15 through June 15 encompasses the rearing and outmigration period for juvenile fall-run chinook and a portion of the outmigration period for steelhead. The July though September period represents the critical juvenile outmigration over-summer-rearing period. October through December represent fall-run chinook salmon spawning and incubation.

In assessing the effectiveness of the shutters, one must keep in mind that the purpose of the cold-water management is to obtain the best balance of LAR water temperatures for the steelhead and Chinook salmon given the limited availability of cold water. Unfortunately, there is not always enough cold water to improve conditions for both species in all months. When this is the case, the cold-water benefits are distributed in a manner that "balances" them between the species. Because the new shutter configuration affords the flexibility to more efficiently manage the benefits, there will be times when it is desirable to increase temperatures, relative to the old shutter configuration, in one or more months in order to better use the benefits in later months.

When a shutter configuration is demonstrated to "not adversely affect" fisheries, the temperature schedules tell us that for this year type, it is better use of the available cold water to allow warmer temperatures in the spring, stabilize temperature fluctuations in the summer, hold the maximum summer temperature below 70 degrees, and conserve cold water for Chinook spawning in the fall. Thus when the new shutter configuration is compared to earlier configurations, during the spring water temperatures are slightly higher but not to an extent that is adversely affecting the fish, during the summer temperatures do not exceed 70 degrees and are relatively stable, and during the fall chinook salmon mortality is measurably decreased by the new shutters.

Adverse Year Lower American River Fishery Impacts

For an adverse year, model simulations illustrate that during the period of April 15 to May 27, temperatures would be roughly equivalent under all shutter configurations. This period encompasses a portion of the fall-run chinook salmon and steelhead juvenile rearing and emigration. Therefore, for this period, the mechanized project would not adversely affect juvenile rearing and emigration relative to other shutter configurations. For the month of June, which is also part of the fall-run chinook salmon and steelhead rearing and emigration period, temperatures are slightly higher under the mechanized project relative to existing conditions, and oscillate higher and lower relative to the future without-project conditions. This oscillation is reflective of cold-water pool management and occurs generally after smolts have emigrated from the river, but prior to the warmest period of the year (i.e., July and August).

During the month of July, which is part of the critical steelhead over-summer-rearing period, temperatures are more stable under the mechanized project because sharp temperature oscillations characteristic of the existing and future without-project conditions are eliminated. For the August through September period, which also corresponds to the critical steelhead over-summer-rearing period and a portion of the fall-run chinook salmon and steelhead adult immigration, temperatures under the mechanized project are generally higher than those under the existing and future without-project conditions, but are generally under 69˚F. Moreover, peak temperatures earlier in the year under the existing and future without-project conditions were lethal to juvenile steelhead, eliminating over-summering rearing of juvenile steelhead. Therefore, lower temperatures under these conditions during the rest of the juvenile steelhead over-summer-rearing period would not likely represent beneficial impacts to juvenile steelhead.

During October through November, which covers a portion of the important fall-run chinook salmon spawning period, temperatures are significantly reduced under the mechanized project relative to the existing and future without-project conditions, with the highest temperature increases occurring under the existing conditions.

Although temperatures during the month of December are well below 56˚F under all configurations considered, the mechanized project significantly reduces fall-run chinook salmon mortality during adverse years, relative to the other configurations considered (Table 5). Finally, as previously discussed, the increased flexibility in reservoir release elevation under the mechanized project allows more efficient use of the cold-water pool available in Folsom Reservoir, and results in a temperature benefit to salmonids in the LAR.

Moderate Year Lower American River Fishery Impacts

During a Moderate year, model simulations show that for the period of April 15 to May 20, temperatures under the mechanized project would be roughly equivalent to or less than temperatures under other shutter configurations. This period encompasses a portion of the fall-run chinook salmon and steelhead juvenile rearing and emigration. Therefore, for this period, the mechanized project would not adversely affect juvenile rearing and emigration relative to other shutter configurations. During the end of May through the month of June, which is still part of the fall-run chinook salmon and steelhead rearing and emigration, the mechanized project would result in increased temperature stability, eliminating the large temperature oscillations associated with the existing and future without-project conditions. This behavior is reflective of cold-water pool management, and generally occurs after smolts have emigrated from the river, but prior to the warmest period of the year (i.e., July and August).

Increased temperature stability is also evident during the period of July through the end of September, which encompasses the critical steelhead over-summer-rearing period and the fall-run chinook salmon adult immigration period. Furthermore, temperatures under the mechanized project for this period (i.e., July through September) would not exceed 67˚F, while there would be occurrences of temperatures exceeding 67˚F under the other configurations considered.

During October through November, which covers a portion of the important fall-run chinook salmon spawning period, temperatures are generally significantly reduced under the mechanized project relative to other shutter configurations, with the highest temperature increases occurring under the existing conditions.

Although temperatures during the month of December are well below 56˚F under all configurations considered, the mechanized project significantly reduces fall-run chinook salmon mortality during moderate years, relative to the other configurations considered (Table 5). Finally, as previously discussed, the increased flexibility in reservoir release elevation under the mechanized project allows more efficient use of the cold-water pool available in Folsom Reservoir, and result in a benefit to salmonids in the LAR.

Favorable Year Lower American River Fishery Impacts

For a Favorable year, simulations illustrate that during mid-April through June, temperatures under the mechanized project would be roughly equivalent or less than temperatures under other shutter configurations. This period encompasses the fall-run chinook salmon and steelhead juvenile rearing and emigration. Therefore, for this period, the mechanized project would not adversely affect juvenile rearing and emigration relative to the other shutter configurations.

During the beginning of July through September, which encompasses the critical steelhead over-summering-rearing period and the fall-run chinook salmon immigration period, the mechanized project results in increased temperature stability, eliminating the large temperature oscillations associated with the existing and future without-project conditions.

During October through November, which covers a portion of the important fall-run chinook salmon spawning period, temperatures are generally significantly reduced under the mechanized project relative to other shutter configurations, with the highest temperature increases occurring under the existing conditions.

Although temperatures during the month of December are well below 56˚F under all configurations considered, the mechanized project significantly reduces fall-run chinook salmon mortality during favorable years, relative to the other configurations considered (Table 5). Finally, as previously discussed, the increased flexibility in reservoir release elevation under the mechanized project allows more efficient use of the cold-water pool available in Folsom Reservoir, and result in a benefit to salmonids in the LAR.

Summary

Overall, the mechanized project represents a potential benefit for the years representative of adverse, moderate and favorable conditions because it stabilizes temperatures, provides greater flexibility and provides cooler temperatures for the important fall-run chinook salmon spawning period relative to the other shutter configurations considered.

Appendix A

Modeled Watt Avenue Temperatures

Adverse Year				
	Modeled Watt Avenue Temperature (^oF)			
Week	Existing (3-2-4)	Future Without-Project (1-1-2-2-3)	Project (7(1)-2)	Mechanized Project (7(1)-2)
15-Apr	65.1	65.1	65.1	65.1
22-Apr	65.4	65.4	65.4	65.4
29-Apr	64.7	64.7	64.7	64.7
6-May	65.0	65.0	65.0	65.0
13-May	66.0	66.0	66.0	66.0
20-May	66.4	63.8	66.4	66.4
27-May	68.1	65.5	65.2	67.0
3-Jun	61.0	62.3	67.2	67.3
10-Jun	63.3	65.3	64.7	67.2
17-Jun	64.1	67.1	66.5	66.3
24-Jun	64.7	67.8	67.7	67.4
1-Jul	66.1	69.2	69.1	67.8
8-Jul	67.9	70.7	66.6	66.6
15-Jul	69.0	64.3	68.0	68.0
22-Jul	69.6	65.4	69.0	68.7
29-Jul	71.0	67.3	63.6	65.7
5-Aug	64.3	65.5	67.0	68.6
12-Aug	66.9	68.2	67.9	69.2
19-Aug	67.7	69.4	69.2	68.9
26-Aug	66.9	69.4	69.0	68.5
2-Sep	63.8	68.0	67.4	66.9
9-Sep	61.3	65.8	65.4	67.5
16-Sep	62.3	65.4	65.3	68.6
23-Sep	63.7	65.9	66.1	67.3
30-Sep	62.6	57.1	62.0	59.5
7-Oct	61.1	57.6	61.2	59.9
14-Oct	61.3	59.1	55.5	60.3
21-Oct	62.0	60.4	58.8	57.2
28-Oct	62.6	61.2	60.3	58.2
4-Nov	60.6	59.2	58.4	57.0
11-Nov	57.7	56.8	56.1	55.1
18-Nov	55.0	55.1	54.7	54.0
25-Nov	54.3	54.0	53.9	53.5
2-Dec	51.4	51.7	51.2	50.8
9-Dec	47.7	47.7	47.7	50.7
16-Dec	45.5	45.2	45.6	50.6
23-Dec	45.1	44.7	44.7	52.5
30-Dec	44.9	44.5	44.5	51.7

Moderate Year				
	Modeled Watt Avenue Temperature (^oF)			
	Existing	Future Without-Project	Project	Mechanized Project
Week	(3-2-4)	(1-1-2-2-3)	(7(1)-2)	(7(1)-2)
15-Apr	61.6	61.6	61.6	61.6
22-Apr	61.7	61.7	61.7	61.7
29-Apr	61.8	61.8	61.8	61.8
6-May	63.5	63.5	63.5	63.5
13-May	64.2	64.2	64.1	60.6
20-May	64.7	64.7	64.0	63.1
27-May	65.1	65.1	60.0	61.1
3-Jun	66.1	66.1	61.0	65.4
10-Jun	67.4	67.4	61.9	64.4
17-Jun	57.9	62.2	63.4	62.7
24-Jun	58.8	63.6	64.6	64.3
1-Jul	60.1	66.4	66.9	66.9
8-Jul	63.0	64.6	65.6	65.1
15-Jul	65.5	66.6	67.6	66.6
22-Jul	67.7	68.4	64.8	64.6
29-Jul	68.8	60.6	66.7	66.6
5-Aug	69.4	63.3	67.7	66.7
12-Aug	61.5	65.1	63.9	64.5
19-Aug	64.2	67.1	66.0	65.9
26-Aug	66.1	59.6	66.8	67.0
2-Sep	67.0	63.7	68.1	65.5
9-Sep	67.4	65.2	65.6	65.6
16-Sep	67.5	65.7	65.8	66.4
23-Sep	67.6	66.3	66.4	66.8
30-Sep	55.1	56.5	54.4	59.3
7-Oct	56.5	57.4	54.6	55.2
14-Oct	57.7	58.2	56.8	54.4
21-Oct	58.8	59.6	58.2	57.3
28-Oct	59.8	59.8	58.9	58.7
4-Nov	57.2	57.4	56.5	56.6
11-Nov	53.8	54.0	53.9	53.6
18-Nov	52.5	52.6	52.6	55.2
25-Nov	51.9	51.9	52.0	55.0
2-Dec	49.5	52.5	49.5	53.0
9-Dec	51.6	49.2	47.5	52.1
16-Dec	47.9	47.0	45.9	50.7
23-Dec	46.5	48.6	45.6	52.5
30-Dec	45.8	51.6	45.5	50.0

Favorable Year				
	Modeled Watt Avenue Temperature (°F)			
Week	Existing (3-2-4)	Future Without-Project (1-1-2-2-3)	Project (7(1)-2)	Mechanized Project (7(1)-2)
15-Apr	61.1	61.1	61.1	61.1
22-Apr	60.8	60.8	60.8	60.8
29-Apr	58.8	58.8	58.8	58.8
6-May	60.1	60.1	60.1	60.1
13-May	60.6	60.6	60.6	60.6
20-May	60.9	60.9	60.9	60.9
27-May	61.5	61.5	61.5	61.5
3-Jun	62.8	62.8	62.8	62.8
10-Jun	64.1	64.1	64.1	64.1
17-Jun	65.6	65.6	65.5	65.5
24-Jun	67.1	67.1	62.9	63.3
1-Jul	58.4	63.9	64.5	64.9
8-Jul	59.7	66.4	66.4	66.4
15-Jul	62.5	64.0	64.4	64.9
22-Jul	65.2	66.9	67.1	66.9
29-Jul	67.2	59.8	64.3	65.8
5-Aug	68.8	63.2	66.6	66.2
12-Aug	69.3	65.1	67.7	67.4
19-Aug	62.9	66.1	68.2	67.5
26-Aug	63.8	66.7	64.9	66.3
2-Sep	64.8	67.1	65.8	65.3
9-Sep	65.2	66.5	65.4	65.3
16-Sep	65.4	66.4	66.0	65.5
23-Sep	65.5	67.1	66.6	66.4
30-Sep	55.0	60.7	56.7	58.5
7-Oct	56.1	59.8	57.2	57.9
14-Oct	57.6	60.1	58.2	57.2
21-Oct	58.8	52.7	54.3	54.5
28-Oct	59.7	56.5	57.2	56.5
4-Nov	58.0	56.1	56.3	56.0
11-Nov	56.9	55.0	55.4	55.1
18-Nov	57.0	55.0	55.3	55.0
25-Nov	56.5	55.3	55.6	55.2
2-Dec	54.1	53.5	53.7	54.2
9-Dec	49.7	49.8	49.8	49.5
16-Dec	46.8	46.7	46.9	49.2
23-Dec	45.4	45.6	45.6	52.5
30-Dec	52.0	44.8	44.8	51.2